TECHNICAL MEMORANDUM

Client:	City of Lynnwood		
Project:	WWTP Process Study		
Project File:	LYNN 118.013.06.0604	Project Manager:	Dan Mahlum, PE
Composed by:	Tom Coleman, PE		
Reviewed by:	Rick Ballard, PE		
Subject:	WWTP Process Evaluation Study		
Date:	July 31, 2019		

Signed: 07/31/19

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Reviewed as Engineer In Responsible Charge

Signed: 07/31/19

1. Background and Introduction

RH2 Engineering, Inc., (RH2) was retained under Task Order No. 6 of the current on-call services agreement to conduct a process study of the City of Lynnwood's (City) Wastewater Treatment Plant (WWTP) to review and summarize existing influent loading conditions and current process performance.

WWTP process performance issues initially centered around performance of the incinerator and the evaluation of options for installing equipment to add kaolin or lime to the solids handling process as a means of enhancing the incinerator's performance. The City relies on the incinerator for treatment and disposal of the primary sludge and waste activated sludge generated by the treatment process. Any limitations of the throughput capacity of the incinerator due to operational problems or other equipment performance issues will directly affect the overall plant capacity.

Additionally, the Washington State Department of Ecology (Ecology) is currently undertaking the Puget Sound Nutrient Source Reduction Project in collaboration with Puget Sound communities and stakeholders to address human sources of nutrients. The nutrient that is currently of primary concern with respect to WWTP discharges directly to the Puget Sound is nitrogen. It is likely that within the next two permit cycles the City will be faced with effluent limits on the amount of total inorganic nitrogen that can be discharged from the WWTP. These nitrogen limits also would significantly affect design capacity and require major plant upgrades. Therefore, another objective of this study was to conduct a preliminary evaluation of the ability of the existing activated sludge process to meet a future nitrogen limit.

Any evaluation of current or future WWTP performance capabilities and capacity must take into consideration that the liquid stream and solids handling facilities are closely interrelated. As an example, if the primary clarifiers were considered as a possible location for the introduction of lime or kaolin into the solids to improve incinerator performance, this could result in the removal of additional biochemical oxygen demand (BOD) from the influent wastewater. This change could be detrimental to the ability of the plant to meet future nitrogen removal requirements.

The performance and capacity of the activated sludge system is significantly affected by the aeration system's capabilities. The aeration system diffusers were replaced and automatic control of the aeration system as a whole was completed in late 2017. This process evaluation also included a detailed review of the data collected in 2018, since the aeration and supervisory control and data acquisition (SCADA) systems were upgraded, and a limited review of historical influent and process data for the past 10 years.

The City provided RH2 with influent data for the past 2 years (2017 and 2018) in the form of monthly incineration and solids handling reports, secondary process control reports, discharge monitoring reports (DMRs), and access to SCADA system data for various plant processes. This data was used to set up a BioWin model of the existing activated sludge process and simulate operation under current loading conditions. The output of the model was compared with recent data to determine if the model's predictions regarding nitrification correspond with current conditions. Additionally, the model was used to understand how the activated sludge process may be configured to accommodate future nitrification/denitrification and nitrogen removal limits. The City also asked RH2 to evaluate the performance of the new aeration system in 2018 and solids handling data. The results of this examination are presented in this technical memorandum.

2. Overview of Existing Treatment Facilities and Permitted Design Capacity

The City's WWTP discharge permit (National Pollutant Discharge Elimination System [NPDES] permit No. WA0024031) specifies the permitted capacity of the plant. The current design criteria as listed in the NPDES Permit are shown in **Table 1**.

Table 1

Design Criteria for Lynnwood WWTP

Parameter	Design Quantity
Maximum Month Design Flow	7.4 MGD
BOD_5 Loading for Maximum Month	15,120 lb/day
TSS Loading for Maximum Month	15,120 lb/day

Under Washington Administrative Code (WAC) 173-220-150(1)(g), flows and waste loadings must not exceed approved design criteria. Ecology approved the design criteria for this WWTP based on the *City of Lynnwood Wastewater Treatment Engineering Report* (HDR Engineering, Inc.) from April 19, 2005.

The "maximum month" criterion is the highest monthly average loading in one calendar year. The BOD and total suspended solids (TSS) loading design criteria for the plant are 15,120 pounds per day (ppd or lb/day) for the average day of the maximum month. In the NPDES Permit Special Condition S4.B: Plans for Maintaining Adequate Capacity, states that when the influent flow reaches 85 percent of the design flow criteria for three consecutive months, the City must submit a plan and schedule to Ecology showing how capacity will be maintained. This requirement will apply when flows reach 6.29 million gallons per day (MGD) for 3 consecutive months. The requirement would also apply when either the BOD or the TSS loads reach 85 percent of the permitted capacity of 15,120 pounds per day for each.

The effluent limits in the current NPDES Permit for the City's WWTP are based on Federal and state regulations that define technology-based effluent limits for domestic wastewater treatment plants. These effluent limits are listed in 40 CFR Part 133 and Chapter 173-221 WAC. These regulations are performance standards that constitute all known, available, and reasonable methods of prevention, control, and treatment (AKART) for domestic wastewater as currently applied to the City's WWTP. **Table 2** identifies technology-based limits for pH, fecal coliform, carbonaceous biochemical oxygen demand ($CBOD_5$), and TSS, as listed in Chapter 173-221 WAC.

The potential impacts of water quality based effluent limits or future technology-based limits for nitrogen removal on effluent limits and design capacity are discussed in **Sections 7** and **8** of this technical memorandum.

Table 2

Current Technology-Based Effluent Limits for the Lynnwood WWTP

<table>
<tr><th>Parameter</th><th>Average Monthly Limit</th><th>Average Weekly Limit</th></tr>
<tr><td>$CBOD_5$ (concentration)</td><td>25 mg/L</td><td>40 mg/L</td></tr>
<tr><td>$CBOD_5$ (concentration)</td><td colspan="2">In addition, the $CBOD_5$ effluent concentration must not exceed fifteen percent (15%) of the average influent concentration.</td></tr>
<tr><td>TSS (concentration)</td><td>30 mg/L</td><td>45 mg/L</td></tr>
<tr><td>TSS (concentration)</td><td colspan="2">In addition, the TSS effluent concentration must not exceed fifteen percent (15%) of the average influent concentration.</td></tr>
<tr><th>Parameter</th><th>Monthly Geometric Mean Limit</th><th>Weekly Geometric Mean Limit</th></tr>
<tr><td>Fecal Coliform Bacteria</td><td>200 organisms/100 mL</td><td>400 organisms/100 mL</td></tr>
<tr><th>Parameter</th><th>Daily Minimum</th><th>Daily Maximum</th></tr>
<tr><td>pH</td><td>6.0 standard units</td><td>9.0 standard units</td></tr>
</table>

Technology-based mass limits are based on WAC 173-220-130(3)(b) and 173-221-030(11)(b). The calculated mass limits shown in **Table 3** are based on technology-based concentration limits in **Table 2**, times the maximum monthly average design flow in millions of gallons per day (MGD), times a conversion factor of 8.34.

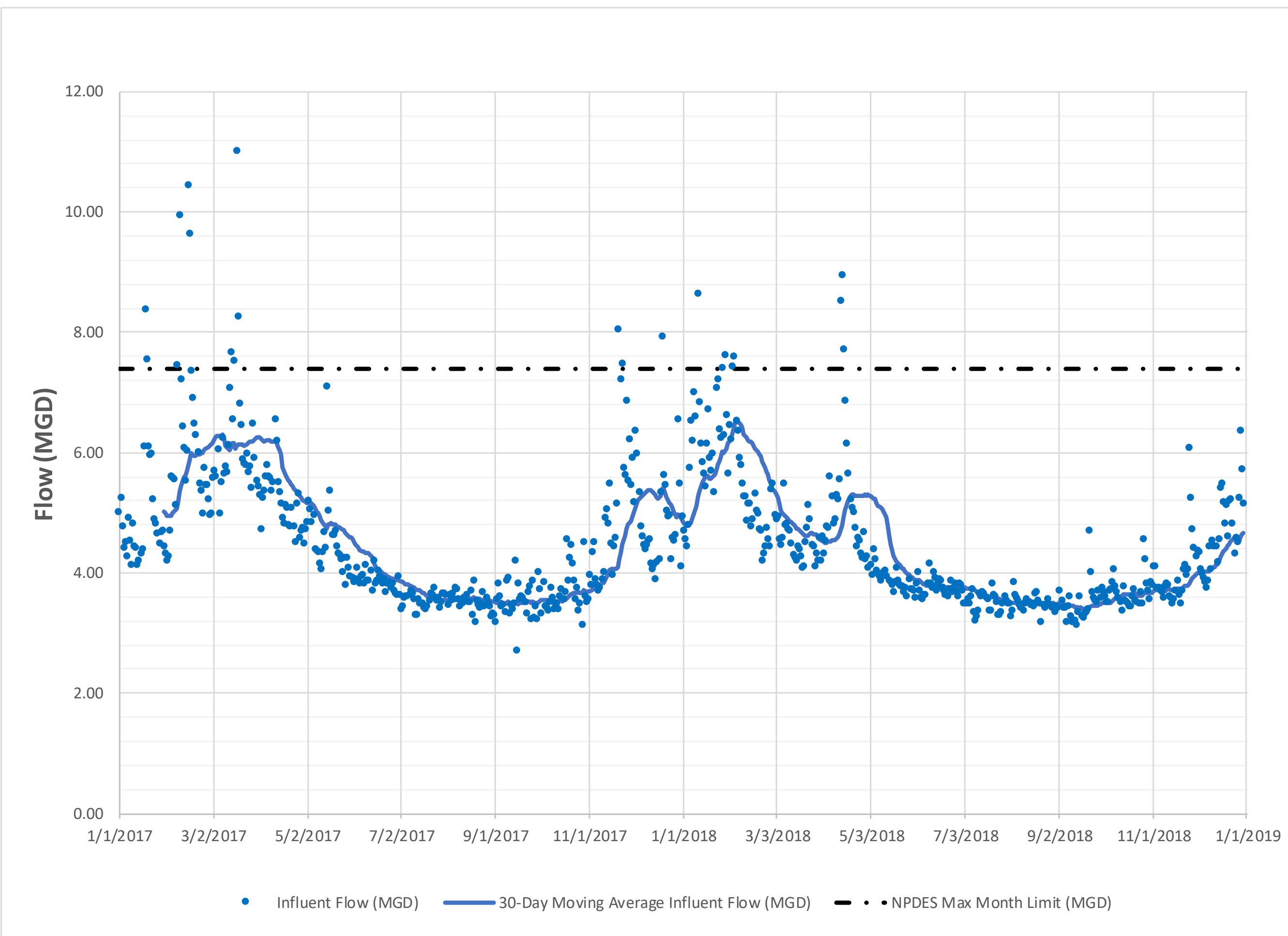
Table 3
Current Technology-Based Mass Effluent Limits for the Lynnwood WWTP

Parameter	Concentration Limit (mg/L)	Mass Limit (lb/day)
$CBOD_5$ Monthly Average	25	1,543
$CBOD_5$ Weekly Average	40	2,469
TSS Monthly Average	30	1,851
TSS Weekly Average	45	2,777

3. Summary of Recent Influent Loading Data

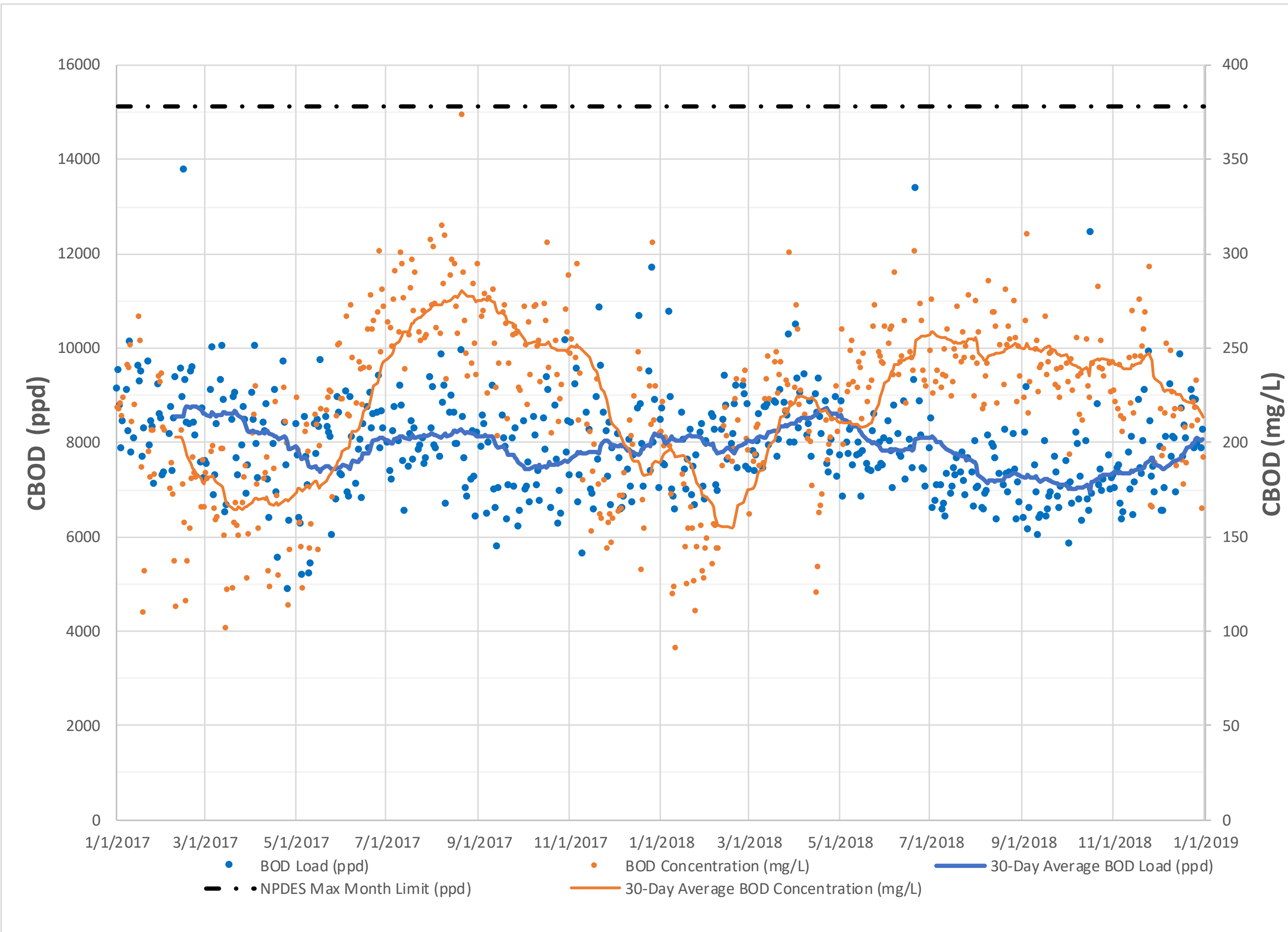
A chart of the influent flow for 2017 and 2018 is shown in **Figure 1**. The chart also shows the Maximum Month Design Flow (MMDF) of 7.4 MGD. The average flow during some of the winter months is getting close to 85 percent of the MMDF.

Figure 1 – Lynnwood WWTP Historical Influent Flow (MGD)



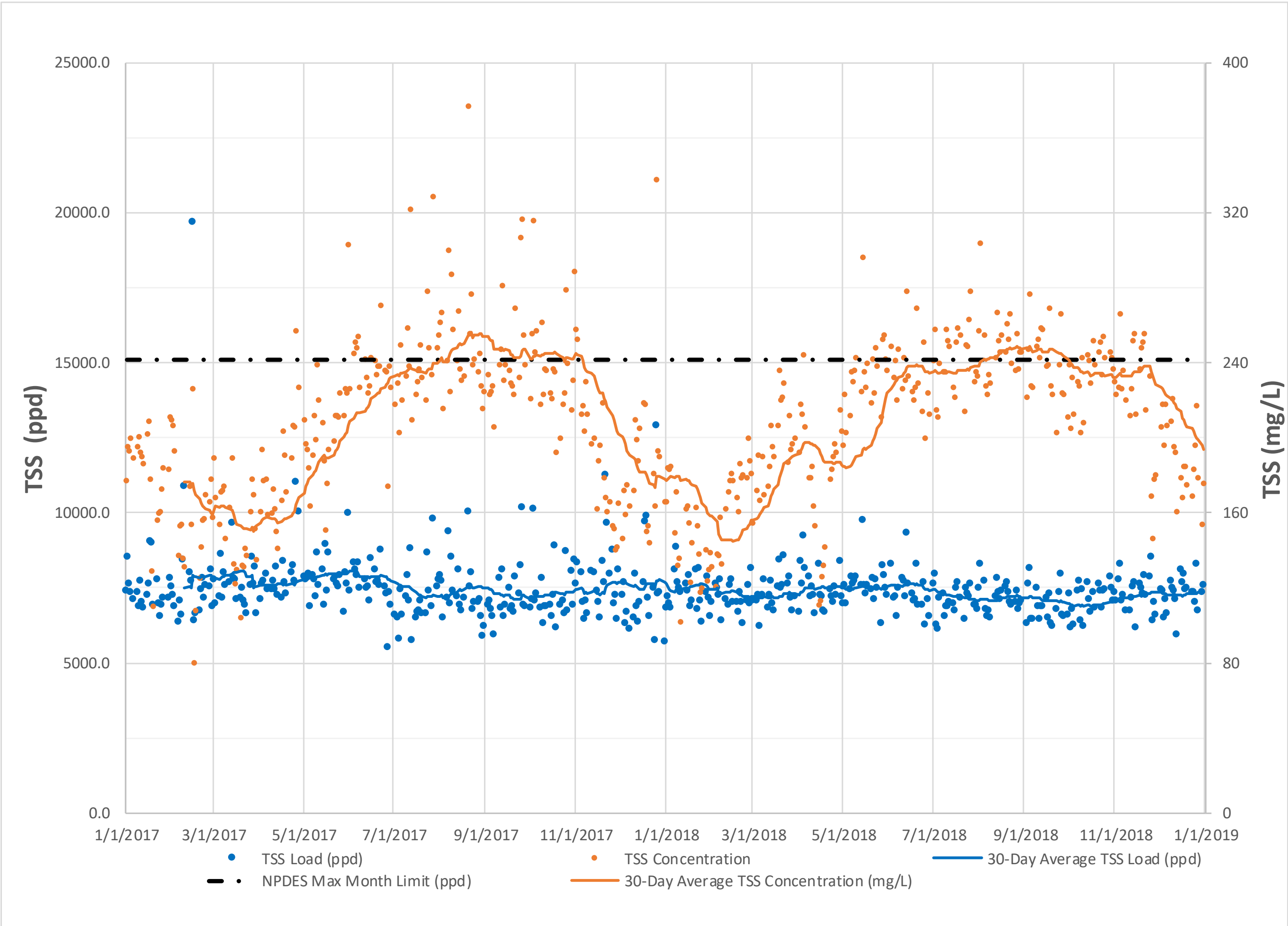
A chart of the influent CBOD mass loading and concentration for 2017 and 2018 is shown in **Figure 2**. The design criterion of BOD_5 loading for maximum month of 15,120 lb/day also is shown on the chart. The moving average of the influent CBOD flow remains around 8,000 lb/day throughout the year or about 53 percent of the design criteria. As would be expected, the influent CBOD concentration varies inversely in proportion to the influent flow rate.

Figure 2 – Lynnwood WWTP Historical Influent CBOD (ppd and mg/L)



A chart of the influent TSS mass loading and concentration for 2017 and 2018 is shown in **Figure 3**. The design criterion of TSS loading for maximum month of 15,120 lb/day also is shown on the chart. The moving average of the influent TSS flow tracks closely with the influent CBOD at around 8,000 lb/day. As with the CBOD, the influent TSS concentration varies inversely in proportion to the influent flow rate.

Figure 3 – Lynnwood WWTP Historical Influent TSS (ppd and mg/L)



4. Summary of Aeration System Performance Under Current Loading Conditions

The WWTP's aeration system consists of three aeration basins which are each split into four cells. A plan view of the aeration basins is shown in **Figure 4**. The majority of the oxygen demand occurs in Cell 3 of each basin, which is significantly larger than the other cells. The volumes of the aeration basins and individual cells are summarized in **Table 4**.

Figure 4 – Lynnwood WWTP Aeration Basin Plan View

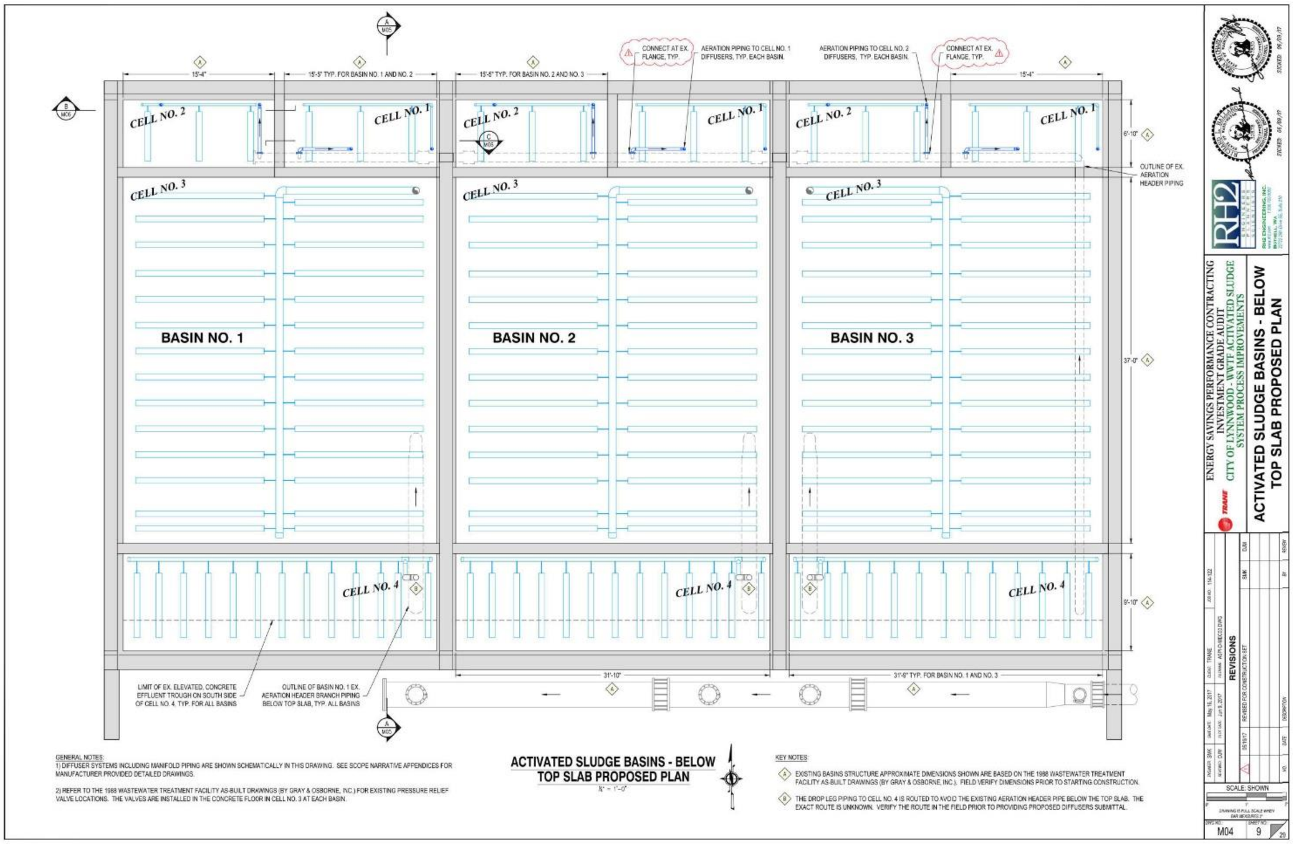


Table 4
Aeration Basin Volumes

Aeration Basin Volumes	Design Information
Number of Basins	3
Side Water Depth	24 feet
Total Volume of Each Basin	309,000 gallons
Number of cells per Basin	4
Volume of Individual Cells	
Cell No. 1	19,500 gallons
Cell No. 2	19,500 gallons
Cell No. 3	212,500 gallons
Cell No. 4	57,500 gallons

The aeration system diffusers were replaced in 2017, along with the automation of the air conveyance system to each of the cells. The basic design information for the new diffusers and the new and existing blowers is summarized in **Table 5**.

Table 5

Aeration System Design Criteria

Aeration Basin	Design Information
Number of Basins	3
Number of Cells per Basin	4
Aeration Rates of Individual Cells	
Cell No. 1 – Minimum for Mixing	13 scfm
Cell No. 1 – Max Air Flow	40 scfm
Cell No. 2 – Minimum for Mixing	13 scfm
Cell No. 2 – Max Air Flow	40 scfm
Cell No. 3 – Minimum for Mixing	141 scfm
Cell No. 3 – Max Air Flow	1,007 scfm
Cell No. 4 – Minimum for Mixing	37 scfm
Cell No. 4 – Max Air Flow	232 scfm
Total Basin – Minimum for Mixing	204 scfm
Total Basin – Max Air Flow	1,319 scfm
Blower Criteria	
Lamson Centrifugal Blowers	
Number	2
Air Flow Ranges (ea.)	Unknown – 2,500 scfm
Neuros Turbo Blower	
Number	1
Air Flow Ranges	1,200 – 2,400 scfm

Recent SCADA system upgrades allow for saving aeration system historical trending data and exporting it to an Excel worksheet for data analysis and charting. In the first step of the aeration system evaluation, the total aeration basin air flow rates were charted for each 3-month quarter in 2018. These four graphs are included in **Appendix A** of this technical memorandum. During each of these three-month periods, only the new Neuros turbo blower was in operation.

It can be observed from the graphs in **Appendix A** that the blower primarily operates within a flow range of 1,200 to 2,400 standard cubic feet per minute (scfm), while the air demand in the aeration basins varies within the range of 700 and 1,500 scfm. The difference between these two ranges of values is due to the fact that air from the blower is being distributed elsewhere in the WWTP. From these graphs it can be confirmed that the maximum output of the turbo blower is around 2,400 scfm. In addition, the maximum air flow the blower is capable of providing to the aeration basins is around 1,500 scfm.

In the next step of the aeration system evaluation, a series of 12 graphs were developed displaying blower flow rate (scfm), blower speed, and the dissolved oxygen (DO) concentration (milligrams per liter [mg/L]) in Cell 3 of each aeration basin. The 12 graphs correspond to each of the months (January through December) of 2018. The purpose of these graphs is to help determine whether the flow capacity of the blower is limiting the ability of the WWTP to provide sufficient aeration to each basin. Each of these 12 graphs is included in **Appendix B**.

In January and February, the blower is clearly capable of meeting system demands, as dissolved oxygen concentrations exceed or meet their setpoint. It also may be observed that the blower rarely reaches its maximum speed. However, in March, DO concentrations begin dipping below their setpoints for extended periods of time, with the blower operating at its maximum speed. In April, the blower once again consistently provided sufficient air to keep up with oxygen demand. In May, another period begins in which the blower goes to maximum speed on a nearly daily basis and is unable to keep pace with the oxygen demand, as evidenced by the fact that the DO correspondingly decreases sharply below the Cell 3 aeration basin set point. This indicates that during the periods of high demand in summer and early fall months (May through October), the blower is incapable of providing sufficient oxygen to meet its determined setpoints. Beginning in late October and continuing through the remainder of 2018, the blower is once again able to meet system demands, with DO levels maintained at or above their setpoints.

Additional graphs showing the relationship between blower flow (scfm) and DO concentrations (mg/L) in the aeration basins are included in **Appendix C**. In addition to blower flow and Cell 3 DO concentration, these graphs display flow in each basin, total flow for all basins, and DO concentrations in Cell 4, which is the second largest cell in each basin. This information is displayed for weekly periods to provide a more detailed view of the trends in the data. These graphs provide additional confirmation of the trends observed in the monthly graphs included in **Appendix B**. As daily influent BOD demands increase (typically around 7:00 or 8:00 p.m.), the blower is consistently unable to provide enough air to meet the dissolved oxygen setpoint. Generally, the oxygen demand in each cell can be met by early morning (around 1:00 a.m.), and the DO setpoint can be maintained.

5. Summary of Recent Effluent Data

The City has occasionally exceeded the effluent limits since the issuance of the previous NPDES Permit on October 30, 2013. Ecology assessed compliance based on its review of the WWTP's discharge monitoring reports (DMRs) and inspections. Violations from 2013 through 2017 are tabulated in the Fact Sheet for the re-issuance of the permit in 2019. Summaries of effluent data from the DMRs for the past 2 years (BOD, and TSS) are shown graphically in **Figure 5** and **Figure 6**. Several violations occurred in the summer of 2017. Additional permit limit exceedances for BOD and TSS occurred late in 2018. The underlying causes of the exceedances were typically related to excessive solids inventories in the activated sludge system due to problems in the solids handling facilities (such as an incinerator shut down).

Figure 5 – Lynnwood WWTP Historical Effluent CBOD (ppd and mg/L)

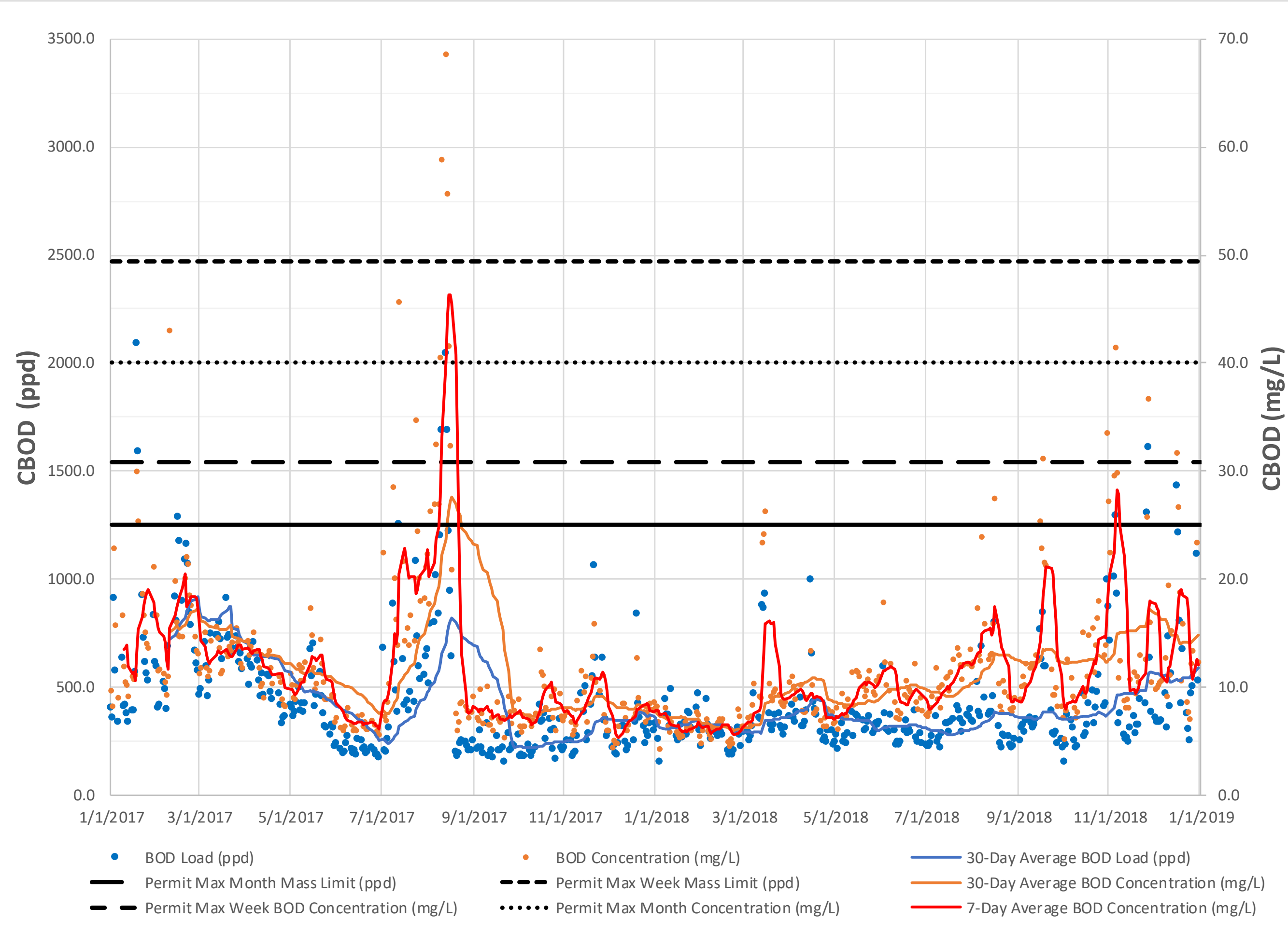
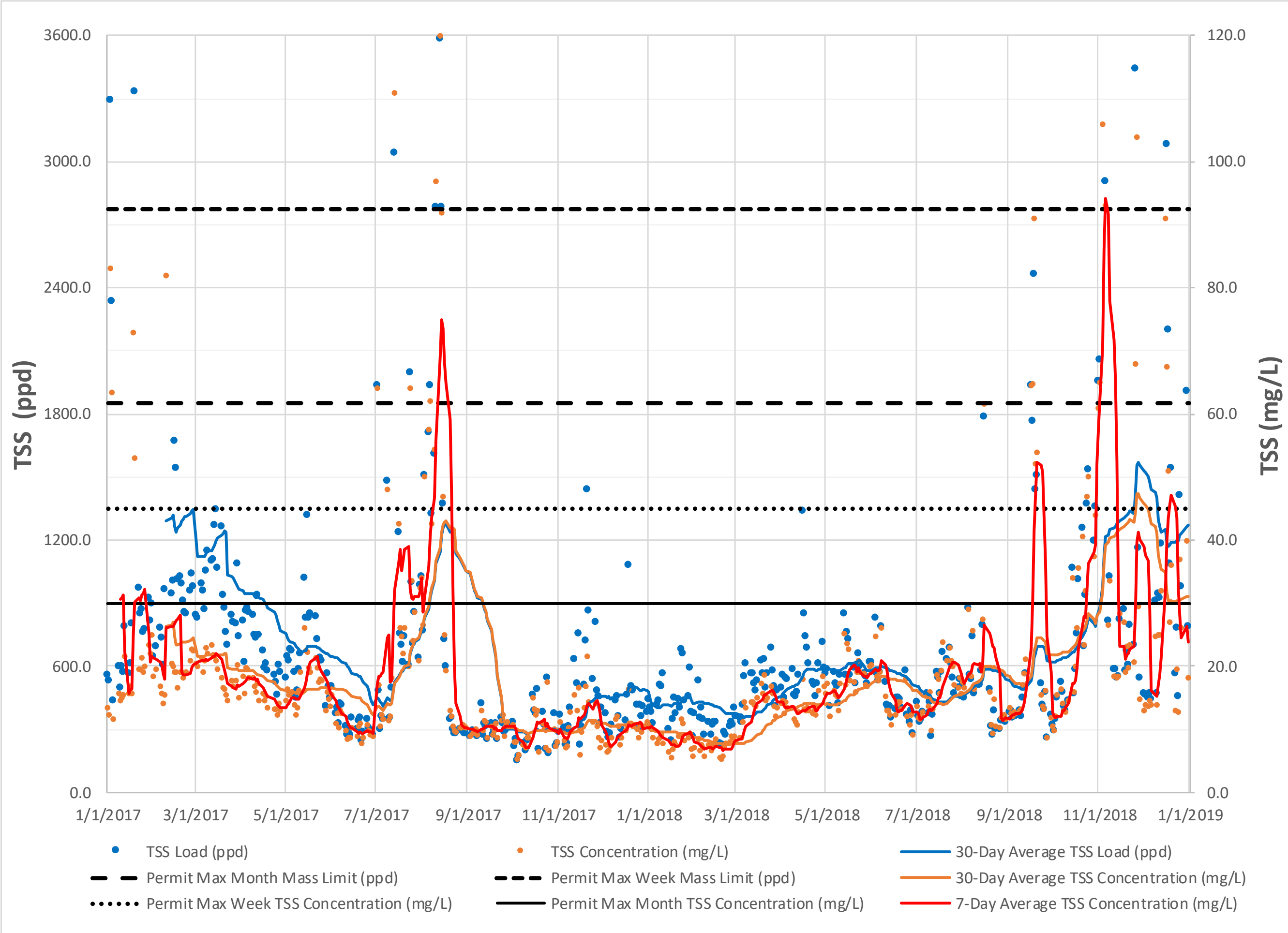


Figure 6 – Lynnwood WWTP Historical Effluent TSS (ppd and mg/L)



6. Solids Production and Solids Handling

The City's WWTP dewaters combined primary and secondary sludge using a screw press and incinerates the dewatered sludge using a fluidized bed incinerator. The inert ash from the incinerator is hauled by truck to a landfill.

According to the City's most recent *Wastewater Comprehensive Plan Update* (Plan) (BHC Consultants 2012), the existing incineration system has sufficient capacity for projected future sludge quantities; however, there are several concerns with the current operation listed in the Plan as follows:

- New air quality standards and the ability to meet them (year 2016 compliance required).
- Energy utilization, efficiency, and sustainability.
- Greenhouse gas emissions.
- Equipment condition and remaining life of the facilities.
- Lack of a viable redundant sludge handling scheme.

A detailed evaluation of the solids handling facilities is beyond the scope of this current process evaluation study. Nevertheless, it is important to note that with respect to planning for future loading conditions and future treatment requirements (such as nitrogen removal), planning for the solid handling systems and the liquid stream treatment processes must be closely coordinated.

For the purpose of this process evaluation study, total solids production and solids burned in the incinerator were plotted against influent BOD and TSS loading. The chart of this data is included as **Appendix D** to this technical memorandum. As there is currently no method for treating solids other than the incinerator, whenever the incinerator is down for maintenance it is necessary to haul solids from the site. The times and quantities of solids hauled also are shown on the chart in **Appendix D**.

7. Proposed Puget Sound Nutrient Management Policies

Many parts of Puget Sound and the Salish Sea have oxygen levels that are below the levels needed for marine life to thrive. In some parts of the Puget Sound, low levels of oxygen persist for most of the year. Ecology is mandated by the federal Clean Water Act to initiate a study when a water body is not in compliance with the state's water quality standards. Puget Sound dissolved oxygen levels are violating these standards in many places based on Ecology’s water quality assessment of state waters. Excess nutrients discharged from wastewater treatment plants, such as nitrogen and carbon, can contribute to low dissolved oxygen levels, which in turn can impact the health of aquatic life.

The Puget Sound Nutrient Source Reduction Project is a collaborative effort with Puget Sound communities and stakeholders to address human sources of nutrients. This work focuses on using the latest science to find the right solutions for regional investments to reduce nutrient sources. The objective is to improve Puget Sound water quality to support salmon and orca recovery and increase resiliency to climate impacts. In 2018, the Puget Sound Nutrient Forum was formed as a large public advisory group for the project to discuss, learn, and provide input on how to reduce human sources of nutrients entering Puget Sound.

Ecology uses the Salish Sea Model and water quality monitoring data to analyze and quantify nutrient impacts from sources both near to and farther away from observed problems. The model helps communities understand the impacts of human nutrient sources (nitrogen from WWTPs in particular) and how potential source reductions could improve Puget Sound water quality.

The latest Salish Sea Model results confirm that discharges of nutrients from human sources are leading to dissolved oxygen problems in many parts of Puget Sound. In 2019 through 2021, Ecology will evaluate different combinations of human source nutrient reduction levels and their potential water quality improvement in Puget Sound. This will inform future actions so that communities invest in strategic solutions for improving marine water quality. The regulatory approaches to meeting nutrient reduction targets may be a Total Maximum Daily Load (TMDL) limit or an alternative to a TMDL, such as technology-based limits on the amount of nitrogen discharged from municipal WWTPs. The next step that will be taken will likely require WWTPs discharging to Puget Sound to initiate facilities planning to evaluate alternatives for meeting proposed nutrient limits. The City’s NPDES Permit was re-issued recently without any requirement to begin facilities planning. It is expected that the next permit to be issued 5 years from now will include such a requirement. However, as the City considers capital improvement projects at the WWTP, it would be helpful to better understand the possible implications of future limits on nitrogen with regard to providing for needed capacity within the existing space available at the WWTP site. Some of these implications are discussed in **Section 8**.

8. BioWin Modeling for Current and Future Conditions

BioWin is a wastewater treatment process simulator that ties together biological, chemical, and physical process models. The activated sludge process model used by BioWin and similar software programs is based on a set of mathematical equations and process state variables that were originally developed by a task group of the International Water Association (IWA).

For the evaluation of the City's WWTP under current and possible future conditions in which nitrogen removal would be required, the BioWin model was run using steady-state simulations. A factor of safety would be applied to the model outputs to account for the diurnal flow variations in the WWTP influent. The model simulations conducted for this study used BioWin's default coefficients and readily available influent wastewater characteristics. When the model is used for facilities planning or design, a more thorough characterization of the influent conditions and a more detailed evaluation of the model coefficients would be recommended.

A schematic of the BioWin model set up to evaluate the current plant design and loading conditions is shown in **Figure 7**.

A schematic of the BioWin model set up to evaluate the potential of the existing WWTP aeration basins to achieve nitrification and denitrification as may be required in a future discharge permit to achieve nitrogen removal is shown in **Figure 8**. To achieve the denitrification that would be needed to meet a nitrogen effluent limit, it would be necessary to operate a portion of the aeration basin volume under anoxic conditions and provide an internal recycle from the last aerated cell to the first anoxic cell. A plan view of the aeration basin configuration modeled for the nitrification and denitrification operating scenario is shown in **Figure 9**.

Figure 7 – BioWin Schematic of Existing Conditions

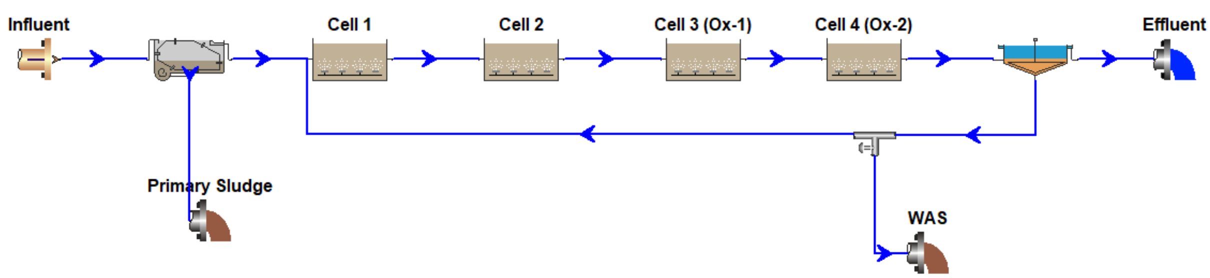


Figure 8 – BioWin Schematic of Plant Under Nitrification/Denitrification Conditions

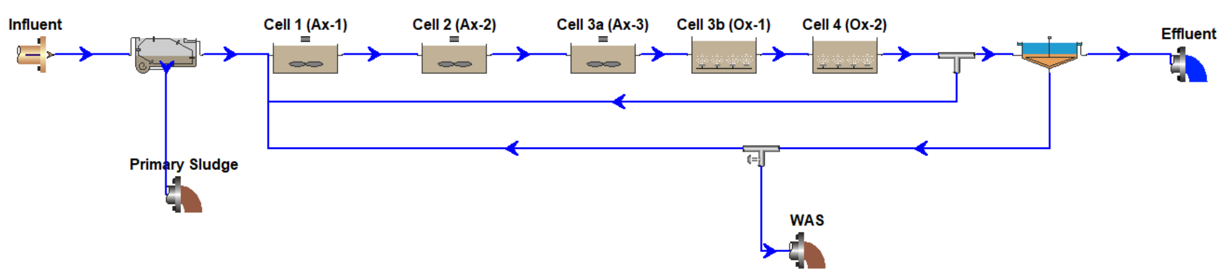
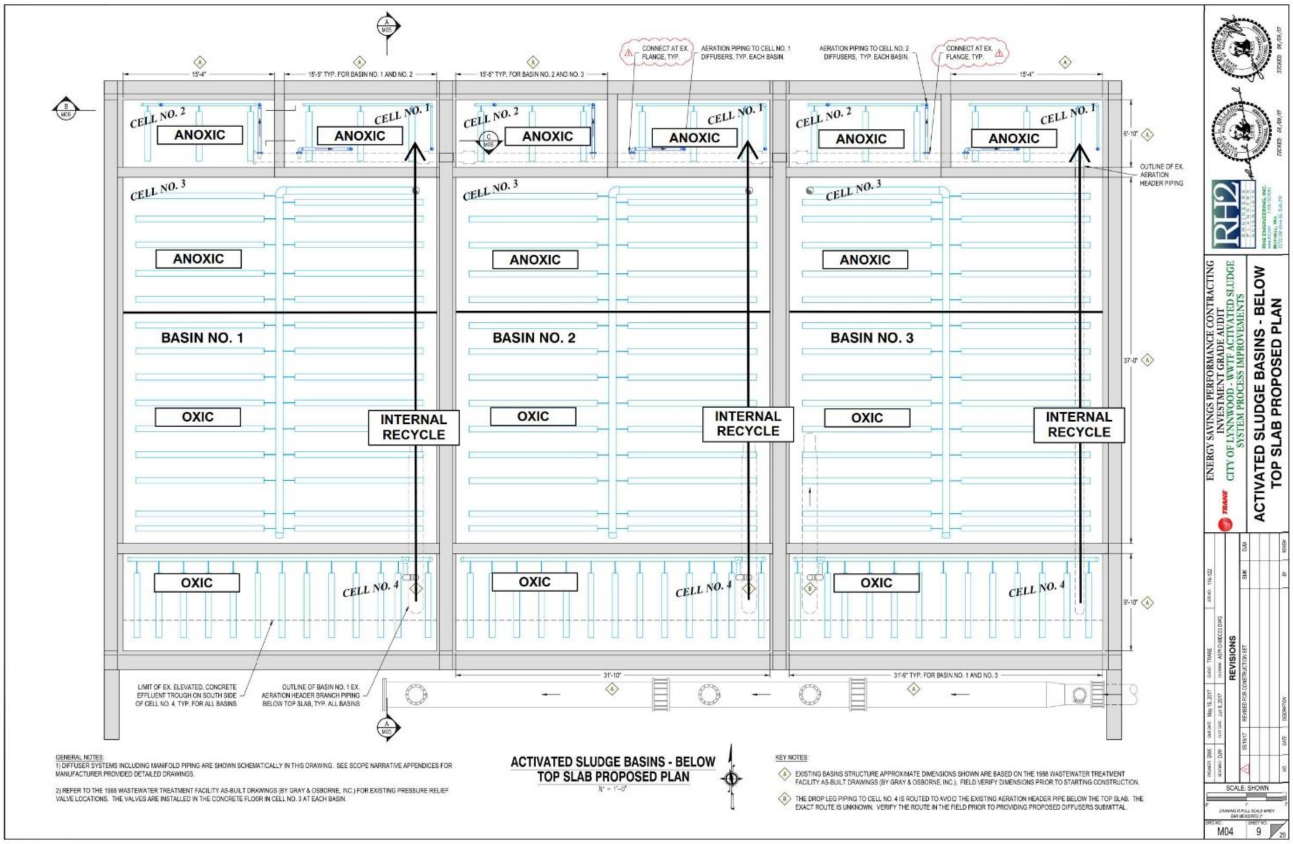


Figure 9 – Proposed Aeration Basin Plan to Achieve Nitrification/Denitrification



The model outputs for the existing aeration basin design configuration are shown in **Table 6**. Model simulations were carried out at an average influent flow of 4.5 MGD with two aeration basins operating and with three aeration basins operating. Another model simulation was carried out at the maximum permitted influent flow of 7.4 MGD with all three aeration basins in operation. The model output shows that the minimum solids retention time (SRT) needed to achieve nitrification is between 3 and 4 days. Applying a safety factor of 2 would suggest a design SRT of 6 to 8 days. The City's WWTP typically operates at an SRT in this range or higher. Since nitrogen removal is not currently required, there is limited data for ammonia and nitrate in the effluent. For the limited data which is available, it appears that only limited nitrification is occurring. If nitrification were occurring at an 8-day SRT as the model predicts, the required air flow rate would be 2,100 to 2,200 scfm. As noted in **Section 4**, this requirement would exceed the amount of air that can be provided to the aeration basins by the Neuros turbo blower by a significant margin. The reason(s) for the lack of nitrification are not fully understood at this time; however, there are reports in the literature (Glen T. Daigger and Thomas E. Sadick, *Water Environment Research,* Vol. 70, No. 7 (Nov. - Dec., 1998), pp. 1248-1257)that the sidestreams from sludge incinerators can have an inhibitory effect on nitrification.

In order to nitrify and denitrify as may be required in a future NPDES Permit, it will be necessary to provide one or more anoxic zones in the activated sludge system, with an internal recycle from an aerated zone to an anoxic zone. For the purpose of this study, it was assumed that Cell 1, Cell 2, and a portion of Cell 3 in each aeration basin would be converted to anoxic zones. The model simulation results for this nitrification/denitrification configuration are shown in **Table 7**.

Table 6
BioWin Output for Existing WWTP Configuration

Lynnwood WWTP Model Results

Parameters	Flow (MGD)	BOD (lb/day)	SRT (days)	Temp (°C)	Effl NH3 (mg/L)	Effl Nitrate (mg/L)	Effl Nitrite (mg/L)	OX1 O2[1] (lb/hr)	OX1 Air Flow[1] (scfm)	OX2 O2 (lb/hr)	OX2 Air Flow (scfm)	Total Air Flow[2] (scfm)	Ox2 VMLSS (mg/L)	Ox2 MLSS (mg/L)	Primary Sludge (lb/d)	WAS (lb/d)	Total Solids (lb/d)
Existing Operating Conditions, 2 Basins, 4 Clarifiers	4.5	9307	2	20	16.26	0.03	4.42	156	836	34	175	1071	1422	1578	5142	4172	9314
Existing Operating Conditions, 2 Basins, 4 Clarifiers	4.5	9307	4	20	0.21	16.02	0.20	281	1626	46	249	1935	2374	2655	5142	3502	8645
Existing Operating Conditions, 2 Basins, 4 Clarifiers	4.5	9307	6	20	0.10	16.71	0.03	307	1795	43	235	2090	3110	3529	5142	3099	8242
Existing Operating Conditions, 2 Basins, 4 Clarifiers	4.5	9307	8	20	0.07	17.06	0.02	319	1871	45	241	2172	3737	4398	5142	2895	8037
Existing Operating Conditions, 2 Basins, 4 Clarifiers	4.5	9307	10	20	0.07	17.28	0.02	327	1925	46	249	2234	4283	5128	5142	2698	7840
Existing Operating Conditions, 2 Basins, 4 Clarifiers	4.5	9307	12	20	0.06	17.44	0.02	333	1966	47	256	2282	4770	5764	5142	2525	7667
Existing Operating Conditions, 3 Basins, 4 Clarifiers	4.5	9307	2	20	12.73	0.04	6.89	165	845	36	182	1117	962	1068	5142	4214	9356
Existing Operating Conditions, 3 Basins, 4 Clarifiers	4.5	9307	4	20	0.20	15.96	0.17	277	1516	45	229	1835	1599	1788	5142	3559	8701
Existing Operating Conditions, 3 Basins, 4 Clarifiers	4.5	9307	6	20	0.10	16.59	0.03	303	1678	43	219	1987	2107	2368	5142	3137	8279
Existing Operating Conditions, 3 Basins, 4 Clarifiers	4.5	9307	8	20	0.08	16.91	0.02	316	1763	44	227	2080	2544	2904	5142	2881	8023
Existing Operating Conditions, 3 Basins, 4 Clarifiers	4.5	9307	10	20	0.07	17.11	0.02	325	1815	46	236	2141	2935	3418	5142	2709	7852
Existing Operating Conditions, 3 Basins, 4 Clarifiers	4.5	9307	12	20	0.07	17.25	0.02	331	1855	47	243	2188	3291	3876	5142	2559	7701
Existing Operating Conditions, 3 Basins, 4 Clarifiers	7.4	15120	2	20	17.00	0.03	4.02	250	1354	54	283	1727	1527	1879	9861	7458	17319
Existing Operating Conditions, 3 Basins, 4 Clarifiers	7.4	15120	4	20	0.21	16.15	0.21	460	2687	75	414	3190	2547	3203	9861	6342	16203
Existing Operating Conditions, 3 Basins, 4 Clarifiers	7.4	15120	6	20	0.10	16.85	0.04	502	2964	71	386	3440	3332	4300	9861	5669	15529
Existing Operating Conditions, 3 Basins, 4 Clarifiers	7.4	15120	8	20	0.07	17.20	0.02	521	3087	72	395	3573	3996	5373	9861	5308	15169
Existing Operating Conditions, 3 Basins, 4 Clarifiers	7.4	15120	10	20	0.07	17.42	0.02	534	3175	74	408	3673	4571	6282	9861	4962	14822
Existing Operating Conditions, 3 Basins, 4 Clarifiers	7.4	15120	12	20	0.06	17.57	0.02	543	3241	76	420	3751	5083	7079	9861	4657	14517

[1]Volume of Ox-1 is assumed to decrease by 50% under Anoxic Bains/Internal Recycle condition
[2]Total Air Flow is from all cells in the aeration basins

Table 7
BioWin Output for WWTP Under Nitrification/Denitrification Conditions

Lynnwood WWTP Model Results

Parameters	Flow (MGD)	BOD (lb/day)	SRT (days)	Temp (°C)	Effl NH3 (mg/L)	Effl Nitrate (mg/L)	Effl Nitrite (mg/L)	OX1 O2[1] (lb/hr)	OX1 Air Flow[1] (scfm)	OX2 O2 (lb/hr)	OX2 Air Flow (scfm)	Total Air Flow[2] (scfm)	Ox2 VMLSS (mg/L)	Ox2 MLSS (mg/L)	Primary Sludge (lb/d)	WAS (lb/d)	Total Solids (lb/d)
Anoxic Basins/Internal Recycle, 2 Basins, 4 Clarifiers	4.5	9307	2	20	15.02	0.02	1.89	133	765	62	347	1113	2428	2964	5142	4134	9277
Anoxic Basins/Internal Recycle, 2 Basins, 4 Clarifiers	4.5	9307	4	20	0.61	3.87	1.27	221	1351	91	536	1887	3863	4328	5142	3008	8150
Anoxic Basins/Internal Recycle, 2 Basins, 4 Clarifiers	4.5	9307	6	20	0.29	5.22	0.17	248	1539	88	521	2060	4909	5525	5142	2557	7699
Anoxic Basins/Internal Recycle, 2 Basins, 4 Clarifiers	4.5	9307	8	20	0.21	5.39	0.09	263	1641	86	509	2150	5782	6526	5142	2265	7408
Anoxic Basins/Internal Recycle, 2 Basins, 4 Clarifiers	4.5	9307	10	20	0.17	5.48	0.06	272	1706	86	505	2211	6523	7378	5142	2048	7190
Anoxic Basins/Internal Recycle, 2 Basins, 4 Clarifiers	4.5	9307	12	20	0.15	5.53	0.05	278	1751	86	504	2255	7165	8119	5142	1878	7020
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	4.5	9307	2	20	11.47	0.03	2.66	145	799	68	366	1166	1652	2012	5142	4180	9322
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	4.5	9307	4	20	0.55	4.33	0.86	225	1309	91	91	1400	2644	2965	5142	3096	8238
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	4.5	9307	6	20	0.27	5.27	0.14	252	1488	88	491	1980	3414	3845	5142	2673	7815
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	4.5	9307	8	20	0.19	5.43	0.08	267	1587	86	481	2069	4069	4598	5142	2396	7539
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	4.5	9307	10	20	0.15	5.51	0.06	276	1651	86	479	2130	4642	5257	5142	2191	7333
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	4.5	9307	12	20	0.14	5.57	0.05	283	1695	86	479	2174	5152	5847	5142	2030	7172
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	7.4	15120	2	20	15.82	0.02	1.75	212	1228	98	559	1787	2605	3525	9861	7370	17231
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	7.4	15120	4	20	0.63	3.72	1.45	358	2209	147	881	3090	4125	5253	9861	5474	15334
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	7.4	15120	6	20	0.30	5.26	0.18	402	2521	144	858	3379	5216	6758	9861	4691	14552
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	7.4	15120	8	20	0.21	5.43	0.09	426	2687	141	837	3524	6126	8026	9861	4178	14038
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	7.4	15120	10	20	0.17	5.52	0.07	441	2794	140	828	3622	6891	9107	9861	3791	13652
Anoxic Basins/Internal Recycle, 3 Basins, 4 Clarifiers	7.4	15120	12	20	0.15	5.57	0.06	451	2867	139	826	3693	7550	10045	9861	3484	13345

[1]Volume of Ox-1 is assumed to decrease by 50% under Anoxic Bains/Internal Recycle condition

[2]Total Air Flow is from all cells in the aeration basins

Because the volume of aerated portions of the aeration basins is reduced by the creation of anoxic cells, the mixed liquor concentration must be proportionately higher to provide a long enough SRT to allow nitrification to occur. With all three aeration basins in service, it would be possible to maintain an SRT of 6 days at a flow of 4.5 MGD while keeping the MLSS below 4,000 mg/L. While a 6-day SRT may be adequate to achieve reliable nitrification at 20 degrees Celsius, it is unlikely to be sufficiently long at colder winter temperatures. To nitrify and denitrify within the existing aeration basin volume at the design flow of 7.4 MGD, it would require MLSS concentration of nearly 7,000 mg/L, even at 20 degrees Celsius.

9. Summary and Conclusions

With the exception of occasional high flows in the winter months due to infiltration and inflow, the City's WWTP is operating within the facility design loading criteria listed in the current NPDES permit. Occasional exceedances of effluent BOD and TSS have occurred during the last permit cycle. These exceedances typically were associated with periods of high solids inventory in the activated sludge system, which can result from incinerator operational problems. A detailed evaluation of the incinerator and associated solids handling systems was beyond the scope of this study; however, the correlation of high solids inventory conditions and incinerator shut downs can be seen in the solids production and handling data presented in **Appendix D**.

Based on the limited data available for effluent ammonia and nitrate, it appears that the activated sludge treatment system does not consistently provide nitrification. In order to meet a possible future effluent limit on nitrogen discharged to Puget Sound, it would be necessary to nitrify and denitrify. Preliminary BioWin activated sludge model simulations indicate that it would not be possible at the current maximum month design flow of 7.4 MGD to nitrify and denitrify within the existing aeration basin volume as would be needed to meet a future nitrogen effluent limit. Meeting the future nitrogen limit would require additional aeration basin volume, conversion to a process that supports higher concentrations of active biomass, or a combination of these approaches.

The next steps in the Puget Sound Nutrient Source Reduction Project, which is currently being led by Ecology, will include requirements in discharge permits, as they are re-issued, to begin facilities planning to evaluate nitrogen removal alternatives. The City's permit was recently re-issued just before this planning requirement was implemented by Ecology, which means it probably will not be an explicit requirement until the next permit cycle. However, if any significant capital improvement projects at the WWTP are under consideration within the next 5 years, it would be in the City's best interests to consider initiating the facilities planning process earlier. The facilities planning effort would include a comprehensive evaluation of both liquid stream alternatives for nitrogen removal and solids handling and treatment alternatives. In the case of the City's WWTP, it will be particularly important to consider the possible impacts of sidestreams from the solids handling process on nitrification and denitrification in the liquid stream biological processes.

Attachments:

1. Appendix A – Aeration Basin Air Flow Rate Charts
2. Appendix B – 2018 Monthly Cell 3 Dissolved Oxygen Concentrations
3. Appendix C – Aeration Basin Blower and Dissolved Oxygen Charts
4. Appendix D – Total Solids Production Chart